Individual differences in the vocabulary skills of children with poor reading comprehension

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Abstract

As a group, poor comprehenders (children who have poor reading comprehension despite age-appropriate decoding abilities) have often been shown to have vocabulary difficulties. However, vocabulary knowledge is complex and could affect reading comprehension in more than one way. We explored this complexity by assessing the vocabulary and oral language skills of poor comprehenders at the individual level. All poor comprehenders displayed some degree of oral language deficit in the context of intact nonword and irregular word reading skills, but patterns of oral language deficit differed across participants. The majority had weak vocabulary skills which took the form of semantic weaknesses, while a minority had age-appropriate vocabulary skills but poor syntactic or listening comprehension skills. Our results support the Simple View of Reading and demonstrate the importance of considering individual variation when developing theories of, and treatments for, poor reading comprehension.

Keywords: vocabulary; reading comprehension; individual differences; oral language; irregular word reading

1. Introduction

The Simple View of Reading (Gough & Tunmer, 1986; Hoover & Gough, 1990) posits that successful reading comprehension requires intact decoding abilities (the ability to sound out or recognize written words) and listening comprehension (or oral language) abilities. Consistent with this, there is a group of children with age-appropriate decoding abilities, but poor reading comprehension due to weak oral language skills (Nation & Snowling, 1997; Yuill & Oakhill, 1991). These children are known as poor comprehenders.

Poor comprehenders have been shown to have a variety of oral language weaknesses, but there is a particularly large body of research exploring the relationship between poor oral vocabulary skills and reading comprehension difficulties (e.g. Catts, Adlof & Weismer, 2006; Clarke, Snowling, Truelove, & Hulme, 2010; Nation et al., 2004; Nation & Snowling, 1998, 1999). In fact, longitudinal and intervention research suggests that vocabulary difficulties are likely to play a part in causing poor reading comprehension (e.g., Clarke, Henderson, & Truelove, 2010; Elwer, Keenan, Olson, Byrne, & Samuelsson, 2013).

However, vocabulary is a complex construct. According to the Lexical Quality Hypothesis (Perfetti, 2007; Perfetti & Hart, 2002), word knowledge is comprised of three main constituents – phonological knowledge (the way a word sounds), orthographic knowledge (a word's written form), and semantic knowledge (what a word means). There is some evidence that poor comprehenders have relative strengths in the phonological and orthographic aspects of word knowledge: As a group, they perform as well as controls on phonological awareness and nonword repetition tasks, and can learn new orthographic forms without difficulty (Catts et al., 2006; Nation, Clarke, Marshall & Durand, 2004; Ricketts, Bishop, & Nation, 2008). This is consistent with their age-appropriate decoding abilities.

In contrast, studies have demonstrated that, as a group, poor comprehenders have weaknesses on a variety of semantic tasks, such as spoken-word picture matching or verbal definition tasks (e.g. Catts et al., 2006; Nation et al., 2004). Thus, their reading comprehension may be poor because they have difficulty understanding the words that they read.

However, semantic skills could also influence reading comprehension through the process of reading aloud. The Triangle model of reading (Plaut, McClelland, Seidenberg, & Patterson, 1996) posits that reading aloud is achieved by a network of distributed phonological, orthographic and semantic codes. Under this model, semantics is always involved in reading aloud to some degree, but contributions from semantics are particularly important for irregular word reading, because irregular words have inconsistent mappings from orthography to phonology. This model predicts that if poor comprehenders have semantic deficits, they are also likely to have irregular word reading deficits. This prediction has been supported by a number of studies (e.g. Nation & Snowling, 1998; Ricketts, Nation & Bishop, 2007).

The suggestion that the two aspects of successful reading comprehension (decoding and oral language) are in fact closely intertwined is problematic for the Simple View. Indeed, studies with samples of poor and typically developing readers have shown that semantic skills contribute to both decoding and oral language aspects of reading comprehension (e.g. Betjemann & Keenan, 2008; Protopapas, Mouzaki, Sideridis, Kotsolakou & Simos, 2013).

Nonetheless, it may be the case that semantic skills are not always linked to decoding abilities, even in the case of irregular word reading. Studies have shown that successful irregular word reading is possible even when individuals have semantic impairments (Blazely, Coltheart, & Casey, 2005; Castles, Crichton & Prior, 2010). These findings have been interpreted within another model of reading, the Dual Route model (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). In this model, reading is accomplished via a sublexical route which converts letters into sounds using grapheme-phoneme correspondence rules, and a lexical route whereby stored lexical representations are accessed. Irregular words can only be read aloud correctly via the lexical route, and stored lexical representations can be accessed either directly from the word's orthographic form, or indirectly via semantics. According to this model, it is possible that there are poor comprehenders who have semantic difficulties, but intact irregular word reading abilities. If such children exist, this supports the Simple View prediction that oral language and decoding abilities can be separately impaired. However, no studies have yet attempted to identify such children.

Furthermore, while many studies show that poor comprehenders have semantic difficulties at the group level, evidence at the individual level demonstrates that some poor comprehenders can perform at an age-appropriate level on tasks of semantics (Cain & Oakhill, 2006; Nation et al., 2004). In fact, the poor comprehender population is heterogeneous and individual poor comprehenders may have very different profiles of oral language skill (Cain & Oakhill, 2006; Nation et al., 2004). However, the vast majority of studies on poor comprehenders are carried out at the group level, obscuring individual differences in oral language skills.

Therefore, this study aimed to address the following questions:

1) What are the patterns of vocabulary and oral language skill in individual poor comprehenders? Do all poor comprehenders have weak vocabulary skills?
2) Are poor comprehenders' low vocabulary scores generally associated with poor semantic skills?
3) If so, are these poor semantic skills generally associated with weak irregular word reading abilities?

To answer these questions, we administered multiple assessments of vocabulary and semantics, because a child's performance on vocabulary tasks is likely to vary according to task demands. For example, tasks such as word-picture matching, definition production and picture naming differ in terms of the depth of semantic knowledge required and the extent of reliance on expressive language and reasoning abilities (Anderson & Freebody, 1981; Ouelette, 2006). The use of multiple vocabulary assessments enabled us to examine whether the nature of vocabulary difficulties was the same across our sample. Our study is the first to explore the vocabulary skills of individual poor comprehenders at this level of detail.

Our study is also unique in that we used a method of statistical analysis from the cognitive neuropsychological literature to compare individual poor comprehender’s test scores to a carefully selected control group. Using this method, we explored patterns of strength and weakness on a detailed battery of standardised and bespoke assessments, selected to tap specific areas of oral language skill.

2. Materials and Methods

2.1. Recruitment and screening

An initial sample was recruited from a primary school in a middle-class area of Sydney. Teachers of classes in Grades 3 to 5 (4th to 6th year of schooling) were asked to nominate children with average word reading abilities for their age and average or below average reading comprehension skills. Consent forms were distributed to parents. Sixty-five children who returned consent forms and gave verbal consent participated in screening assessment.

Screening revealed 13 participants who fit the criteria for specific reading comprehension difficulties, and nine who met criteria for controls (see below). We recruited further controls through a club for children and parents interested in participating in cognitive research (the Neuronauts Brain Science Club) at Macquarie University, Sydney. Members received a newsletter advertising various research participation options. Parents contacted the first author directly if interested in participating in the study. Of 30 children screened, 11 met control criteria and could be matched to poor comprehender participants in terms of age and grade level at the time of language and cognitive assessment (see below).

Our final sample consisted of 13 (11 female) poor comprehenders and 20 (9 female) reading-accuracy matched controls. Children were aged between 9 and 11. All participants had been attending school in Australia since Kindergarten and spoke English as their primary language[1]. There had been no previous concerns noted about reading or oral language for any of the children.

Participants were screened for reading comprehension using Form 1 of the Neale Analysis of Reading Ability (NARA; Neale, 1999). During administration of the NARA, participants read a series of passages aloud and are asked open-ended questions about the passages. The number of passages read is determined by a child's passage reading accuracy.

Reading comprehension was also screened on Form A of the York Assessment of Reading for Comprehension Passage Reading Australian Edition (YARC; Snowling et al., 2012). The YARC also requires children to read passages aloud and answer open-ended questions. On the YARC, children read aloud and answer questions on two passages. Passage levels are determined by the child's age, reading ability and comprehension ability.

The Castles and Coltheart Reading Test 2 (CC2; Castles, Coltheart, Larsen, Jones, Saunders, & McArthur, 2009) was used to screen single word and nonword reading accuracy. We presented 40 nonwords and 40 irregular words interspersed, in order of increasing difficulty. Children read the words or nonwords aloud from cards. A stopping rule of five consecutive errors applied to each item type.

[1] Note that two of the poor comprehenders spoke a language other than English at home, and this may have had an influence on their language scores. For the purposes of this paper, we are interested in whether low oral language scores co-occur with reading comprehension deficits, but make no claims about the initial causes of these poor scores. Nonetheless, it would be interesting for future studies to explore whether the language skills of monolingual poor comprehenders differ from those from multilingual language backgrounds.

At screening, children were also assessed on the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999), a test of word reading fluency. This was not used as a diagnostic measure, but rather to explore whether there were any differences in fluency skills between the two groups. The TOWRE contains two subtests, a Sight Word Efficiency subtest (children read lists of words as fast as possible), and a Phonemic Decoding Efficiency subtest (children read lists of nonsense words as fast as possible). The child's score is the number of items they read correctly within 45 seconds. Because US-based TOWRE norms have been shown to overestimate the performance of Australian children, Australian norms (Marinus, Kohnen & McArthur, 2013) were used.

Criteria for group membership were as follows[2]:

a) Poor comprehenders: reading accuracy scores on both CC2 subtests (irregular words and nonwords) within the average range (standard scores between 85 and 115, z-scores between 1 and -1), and a reading comprehension standard score of less than 85 on either the NARA, the YARC, or both[3], with this comprehension score being at least one standard deviation below their lowest accuracy score on the CC2, NARA accuracy or YARC accuracy measures.

b) Controls: all reading accuracy (CC2 Nonword and Irregular word reading, NARA and YARC accuracy) and reading comprehension (both NARA and YARC) scores within the average range.

Mean standard scores for poor comprehenders and controls on each screening measure are shown in Table 1 along with the results of Mann-Whitney U tests comparing the

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[2] Studies of poor comprehenders use a variety of different selection criteria. We chose to utilise cut-off scores as these are commonly used (e.g. see Adlof & Catts, 2015; Keenan & Meenan, 2014; Pimperton & Nation, 2014) and therefore allow comparability to other studies. However, see Li and Kirby (2014) and Tong, Deacon, Kirby, Cain and Parrilla (2011) for examples of an alternative method of group selection.

[3] Different reading comprehension tests tap different underlying skills (Keenan, Betjemann & Olson, 2008). Therefore, we elected to use two different comprehension assessments to avoid limiting our conclusions to the sample of poor comprehenders identified by a single test.

groups. As expected, poor comprehenders had significantly lower standard scores than controls on the reading comprehension measures, but not on the reading accuracy measures.

Table 1

Mean Standard Scores of Poor Comprehenders and Controls at Screening

Measure	Poor Comprehenders		Controls		Mann-Whitney U		
	Mean	Median	Mean	Median	*U*	*p*	*r*
NARA Text Reading Comprehension	81.00 (6.10)	82	97.36 (7.90)	95.5	10.50	<0.001**	0.77
YARC Text Reading Comprehension	89.92 (9.05)	90	100.70 (5.44)	100	42.00	0.001**	0.57
NARA Text Reading Accuracy	104.31 (8.62)	103	104.95 (5.59)	105.5	103.00	0.33	0.17
YARC Text Reading Accuracy	100.15 (6.90)	100	99.00 (7.16)	98	121.00	0.76	0.06
CC2 Nonword Reading Accuracy	100.66 (5.63)	102.1	96.36 (7.90)	94.68	88.50	0.13	0.27
CC2 Irregular Word Reading Accuracy	106.60 (8.25)	105.4	103.41 (5.64)	103.45	95.50	0.21	0.22

Note. Standard deviations are in parentheses. *$p < 0.05$ **$p<0.01$

2.2. Language and cognitive assessment

Participants were assessed on standardised tests and on experimenter-designed tasks tapping knowledge of orthography, phonology and semantics of the same words, to determine the relative strength of these different aspects of vocabulary knowledge. Semantic skills were assessed using several tasks which varied in depth of semantic processing and expressive language demands.

Participants were also assessed on two oral language tasks tapping skills beyond the word level, to determine whether their deficits extended to broader oral language skills. Finally, they were assessed on non-verbal working memory and reasoning tasks to ensure that their reading comprehension difficulties were not a consequence of more general intellectual difficulties.

Participants were tested individually by the first author, either in a quiet room at school or in a testing laboratory at Macquarie University. Assessment took approximately 150 minutes per child. Children were given rest breaks throughout the assessment.

Tests with spoken responses were audio recorded and scored from these recordings. All tests were scored by four trained research assistants who were blind to group membership. One primary research assistant scored approximately 60% of all the assessments, while the others scored the remaining 40%. For the definition production and listening comprehension assessments (see below), the primary research assistant double-scored one randomly-selected test from each other rater. This amounted to 9% of the total data from each assessment. Percentage agreement between the primary research assistant and each other research assistant was then calculated, and these figures were averaged to constitute the percentage of inter-rater agreement for these tests (see test description sections below). Any disagreements were resolved by discussion between the raters.

Spearman's rho reliability values for the experimenter-designed tasks range between 0.70 and 0.95. A description of all assessments is provided in Table 2. Further details of test development and reliability are reported in (reference removed for blinding purposes).

Table 2
Description of assessments

Assessment	Authors	Description
Lexical semantics		
Definition production[a]	Removed for blinding purposes	Children heard spoken words and were asked to say anything they knew about the word's meaning.
Definition recognition[a]	Removed for blinding	After being asked to provide each definition, children heard three spoken definitions and were asked to say which best matched the target word.
PPVT-IV	Dunn & Dunn, 2007	Children heard a word and saw an array of four pictures. They were required to point to the picture representing the word.
Conceptual semantics		
Picture-picture association	Items from Biran & Friedmann, 2007, and Pitchford, Funnell, Ellis, Green & Chapman, 1997	Children selected which of two stimulus pictures were associated with a target picture by pressing a key. Accuracy and reaction times were recorded.
Naming		
ACE 6-11 Naming Test	Adams, Cooke, Crutchley, Hesketh & Reeves, 2001	Children named pictures aloud.
Lexical phonology		
Auditory lexical decision[a]	Removed for blinding	Children heard a series of words and nonwords (formed by changing one phoneme of the experimental words), and stated whether they thought the stimulus was a word or not.
Phonological processing		
AWMA Nonword Recall	Alloway, 2007	Children heard a sequence of nonwords and had to recall them in the correct order.
Orthography		
CC2 Irregular word reading	Castles et al., 2009	Children read aloud irregular words.
Vocabulary reading task[a]	Removed for blinding	Children read aloud the words from the definition and auditory lexical decision tasks.
Syntax		
Sentence-picture matching	Items from Friedmann & Novogrodsky, 2002	Pictures depicting three characters (for example, two women and a girl) were shown on a computer screen. Children heard a sentence relating to the picture and pointed to the correct referent for each sentence. Ten of the sentences were subject wh- questions ("Which lady is pinching the girl?"), ten were object wh- questions ("Which lady is the girl pinching?"), ten were subject relatives ("Point to the lady that is pinching the girl") and ten were object relatives ("Point to the lady that the girl is pinching").
Broader oral language		
Listening comprehension	Neale, 1999	Passages 4, 5 and 6 of Form 2 of the NARA (Neale, 1999) were read aloud to participants. After hearing the passages, children were asked 8 open-ended questions about each passage as per the standard administration procedure (24 questions in total).
Memory and reasoning		
AWMA Spatial Recall	Alloway, 2007	Children saw a series of pairs of shapes and were required to say whether two shapes were the same, and then recall the spatial location of red dots which appeared above each pair, in the order they appeared. The number of shape pairs increased with each trial. This task returned a Processing score (number of correct similarity judgements) and a Recall score (ability to remember the location of the red dots in order).
WASI-II Matrix Reasoning	Wechsler, 2011	Children were asked to identify which of 5 pictures represented the next step in a visual matrix.

Notes: PPVT-IV = Peabody Picture Vocabulary Test Fourth Edition. ACE 6-11 = Assessment of Comprehension and Expression 6-11. AWMA = Automated Working Memory Assessment. CC2 = Castles and Coltheart Reading Test 2. NARA = Neale Analysis of Reading. WASI-II = Wechsler Abbreviated Scale of Intelligence Second Edition. [a] The same words were used for all these tasks (see Appendix A)

3. Results

Results were analysed to determine what patterns were evident at the group level, and whether these held for individual participants.

3.1 Group Level Results

3.1.1. Analysis

Our sample contained participants of different ages and school grades. In order to combine the data and avoid confounding age with reading and language skill, we regressed each child's raw score for each measure on their age and age squared. The resulting standardised residuals were a measure of each child's performance on a particular task relative to other children, once the influence of age had been removed (Hua & Keenan, 2014). These were transformed into standard scores with a mean of 100 and a standard deviation of 15. These scores were used in all subsequent group-level analyses and will be referred to as "sample standard scores" to distinguish them from standard scores obtained from standardised tests.

Both accuracy and reaction time data were analysed for the conceptual semantics task. Reaction time analyses were carried out using each participant's mean reaction time (RT) from correct trials. RTs more than three standard deviations from each participant's mean were excluded. This resulted in a loss of 2.7% of the data for the poor comprehenders, and 2.4% of the data for controls.

For many of the measures, data did not meet assumptions of normality or equality of variance. Therefore, non-parametric Mann-Whitney U tests were carried out. We corrected for multiple comparisons using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995). Results for poor comprehenders and controls at screening are displayed in Table 1 above. Mean sample standard scores (created from raw scores regressed on age and age squared) and standard deviations for both groups on all measures are shown in Table 3.

Table 3
Group-Level Results

Measure	Poor Comprehenders		Controls		Mann-Whitney U		
Screening measures	Mean	Median	Mean	Median	*U*	*p*	*r*
NARA Comprehension[a]	89.00 (9.66)	85	107.10 (12.74)	105.5	35.5	< 0.001*	0.61
YARC Comprehension[a]	89.54 (12.51)	89	106.80 (11.53)	106	34	<0.001*	0.62
CC2 Nonword Reading[a]	103.69 (12.61)	104	97.6 (15.39)	98.5	96.5	0.22	0.21
CC2 Irregular Word Reading[a]	102.23 (16.70)	105	98.6 (13.06)	98	111	0.50	0.12
Language, cognitve and fluency measures							
TOWRE Sightword Efficiency[a]	100.08 (15.79)	103	100.00 (14.23)	97	123	0.81	0.05
TOWRE Pseudoword Decoding[a]	101.08 (17.54)	102	99.35 (12.55)	99.5	123.5	0.81	0.04
Vocabulary reading	96.08 (3.95)	100	102.55 (14.55)	104.5	98	0.25	0.21
PPVT-IV	92.38 (12.45)	87	105.05 (13.70)	104.5	69	0.02	0.39
Definition production task	90.46 (7.40)	89	106.05 (14.72)	105	47.5	0.002*	0.53
Definition recognition task	91.62 (11.24)	94	105.40 (14.02)	107	59	0.008*	0.46
Conceptual semantics task accuracy	93.46 (14.22)	91	104.25 (13.48)	103	70.5	0.03	0.38
Conceptual semantics task reaction time	104.54 (9.60)	106	97.10 (16.66)	99.5	87	0.12	0.28
ACE 6-11 Naming	98.23 (16.39)	98	101.37 (13.33)	103	117.5	0.82	0.04
Auditory lexical decision task	93.00 (13.13)	99	104.40 (13.93)	105	69	0.02	0.39
AWMA Nonword Recall	98.92 (15.20)	105	95.58 (27.05)	103	120	0.91	0.02
Syntax task - object sentences[b]	92.38 (17.84)	97	104.95 (9.67)	109	65.5	0.02	0.41
Listening comprehension task	90.46 (12.17)	89	106.35 (12.63)	104	41.5	0.001*	0.57
AWMA Spatial Recall Processing	99.15 (14.14)	101	100.56 (15.16)	97	114	0.92	0.02
AWMA Spatial Recall	95.69 (7.89)	97	103.22 (17.39)	97.5	89	0.28	0.20
WASI-II Matrix Reasoning	94.69 (10.11)	89	103.5 (16.02)	105	84.5	0.09	0.29

Notes. Standard scores shown here were derived from the experimental sample and not from standardised tests. Age differences were controlled for by regressing raw scores on age and age squared. Standard deviations are in parentheses. [a] Assessed at screening. [b] All participants were at ceiling on subject questions, therefore these were not analysed. *Significant after controlling for multiple comparisons

3.1.2. Results.

At the group level, as expected, there were no significant differences between the groups on any of the reading accuracy measures (nonword reading, irregular word reading, fluency or vocabulary reading). No significant differences were observed on the nonword recall task, the spatial recall task or the Matrix Reasoning task. Before controlling for multiple comparisons, poor comprehenders scored significantly below controls on the majority of semantic measures, the lexical phonology (auditory lexical decision) task, and the syntax and listening comprehension tasks. However, after controlling for multiple comparisons, only the differences on the listening comprehension and definition production and recognition tasks remained significant. Thus, evidence at the group level supports the view that poor comprehenders have weak vocabulary and listening comprehension skills in the context of intact decoding abilities and intact memory and reasoning abilities.

3.2. Individual-level results

3.2.1 Analysis

Previous research suggests that the oral language difficulties of poor comprehenders may be subtle and difficult to detect (Catts, 2009; Nation et al., 2004). A poor comprehender may score within the low average range on a standardised task, but that level of skill may not be sufficient to allow the child to succeed on reading comprehension tasks in the classroom context. Thus, poor comprehenders' scores may fall just within the average range on a standardised task, but may nonetheless be significantly lower than the scores obtained by children who have average reading comprehension skills. For this reason, we compared the scores of individual poor comprehenders to the scores of a group of age-matched controls with average reading comprehension and reading accuracy, using a modified t-test procedure, SinglimsES (http://homepages.abdn.ac.uk/j.crawford/pages/dept/SingleCaseMethodsComputerPrograms.HTM; Crawford, Garthwaite, & Porter, 2010; Crawford & Howell, 1998).

The SinglimsES test is designed to be used with control samples of less than 50 participants and is accurate for control samples as small as five participants (Crawford & Howell, 1998). This test calculates how unusual a particular case's score is likely to be within a relevant control population, extrapolated from the test scores of the control sample. This is expressed as the percentage of the estimated control population whose scores would be expected to fall below the given case's score.

We considered a child to have a deficit on a particular skill when 90% of the control population would be expected to obtain a score higher than that of the poor comprehender – in other words, when 10% of the control population's scores were estimated to fall below a poor comprehender's score. This is equivalent to approximately 1.3 standard deviations below the mean.

SinglimsES also reports *p* values for the difference between the case of interest and the control sample. In our sample, when a poor comprehender's score fell below that of 5% of the control population, this was equivalent to $p < 0.05$, and when their score fell below that of 10% of the population, *p* is between 0.05 and 0.10. This meant that our choice of the 10% cut-off entailed acceptance of an alpha level of 0.10. Since it was our intention to identify subtle, difficult-to-detect oral language difficulties, adoption of an alpha level of 0.05 in conjunction with our small sample size was likely to lead to an unacceptably high risk of Type II errors. Therefore, we believe an alpha level of 0.10 is warranted.

Because the scores of poor comprehenders were compared to those of grade- and age-matched controls, all individual-level comparisons were calculated using raw accuracy scores (or mean RT for reaction time data). The only exceptions were reading comprehension, word reading accuracy and fluency – these tasks were assessed at screening, which took place 6 months before the other assessments for children from the school sample, but only one to two weeks before for children from the Neuronauts sample. These comparisons were therefore calculated using test standard scores.

Descriptive statistics for control participants are displayed in Table 4. Table 5 presents the estimated percentage of the population from which the control children are drawn who would score worse than a poor comprehender for each measure (as calculated using the SinglimsES statistics). A child whose score falls below the bottom 10% of the control population is considered to have difficulties with that skill (see above). Mean raw scores of controls and individual poor comprehenders are shown in Appendices B and C.

Table 4

Descriptive Statistics for Control Participants

	Grade 4	**Grade 5**	**Grade 6**
Number of participants	7	6	6
Mean age (years:months)	9:7	10:5	11:4
Standard deviation (months)	2.37	2.00	3.00

Notes. One control participant in Grade 5 and one in Grade 6 were not tested on the AWMA due to equipment failure. In addition, one control child in Grade 5 was not tested on the ACE 6-11 due to testing interruptions. Thus, there is one less control participant for each of these comparisons. However, there were never less than 5 controls on any one measure (5 is the minimum number of controls required for reliability of the statistical analysis; Crawford & Howell, 1998).

Table 5

SinglimsES Results

Measure	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13
Grade	4	4	4	4	4	4	4	5	5	5	5	6	6
Age (years:months)	9:1	9:6	9:0	8:11	9:5	9:9	9:8	10:0	9:10	10:2	10:4	11:5	11:3
Screening measures													
NARA Comprehension[a]	1.36*	1.12*	0.92*	2.52*	0.26*	4.76*	3.11*	2.07*	3.54*	0.54*	3.54*	2.62*	34.39
YARC Comprehension[a]	0.81*	2.62*	18.36	9.05^	0.35*	0.16*	0.52*	91.16	28.15	28.15	0.71*	35.55	0.71*
CC2 Nonword Reading[a]	60.76	77.28	74.07	81.55	56.52	23.76	46.36	91.00	77.06	79.42	23.54	88.41	63.71
CC2 Irregular Word Reading[a]	2.95*	22.94	49.68	39.07	90.32	80.62	41.38	99.36	99.87	97.86	93.91	50.00	9.64^
Language, cognitive and fluency measures													
TOWRE Sightword Efficiency[a]	60.76	37.59	81.53	77.97	6.30*	81.53	96.12	94.56	54.79	75.65	80.25	39.99	30.02
TOWRE Pseudoword Decoding[a]	64.56	44.97	13.67	62.30	11.16	13.67	44.97	99.95	84.13	84.13	39.16	70.23	86.63
Vocabulary reading task	13.50	19.06	55.15	22.45	16.08	11.29	60.19	57.31	5.82^	22.16	0.20*	75.73	58.30
PPVT-IV	3.92*	7.77^	12.15	0.94*	6.82^	50.91	60.23	53.98	2.33*	4.12*	1.53*	10.54	45.82
Definition production task	8.04^	7.62^	9.93^	6.85^	7.22^	12.23	25.25	26.27	14.40	12.66	9.72^	7.28^	12.37
Definition recognition task	7.49^	6.31^	6.38*	1.62*	1.91*	20.00	39.28	23.83	14.33	23.83	18.61	0.81*	21.47
Conceptual semantics task accuracy	2.45*	0.51*	50.00	50.00	13.22	86.78	13.22	98.87	63.94	98.87	3.06*	8.86^	8.86^
Conceptual semantics task reaction times	68.60	6.18^	9.07^	0.88*	28.24	82.50	19.74	56.07	20.16	14.85	40.40	39.19	11.90
ACE 6-11 Naming	14.56	14.56	1.60*	0.80*	0.13*	47.11	91.35	77.47	43.74	14.63	15.27	31.63	82.15
Auditory lexical decision task	17.24	7.02^	9.55^	9.55^	5.15^	32.94	49.40	33.81	14.48	14.48	14.48	12.31	0.01*
AWMA Nonword Recall	81.43	72.91	18.57	18.57	81.43	72.91	72.91	15.37	50.00	50.00	0.31*	20.46	63.75
Syntax task - object sentences[b]	18.89	0.26*	45.54	45.54	45.54	18.89	6.21^	38.42	0.19*	38.42	10.97	0.46*	77.71
Listening comprehension task	9.69^	3.85*	7.14^	9.69^	5.24^	9.69^	76.31	7.71^	15.44	1.32*	1.86*	10.85	31.27
AWMA Spatial Recall Processing	27.81	41.17	35.13	43.25	3.64*	13.32	4.19*	44.39	17.89	39.25	48.57	22.79	93.01
AWMA Spatial Recall	26.83	29.65	31.13	29.65	17.44	25.49	19.50	45.66	9.90^	33.34	39.33	25.70	86.70
WASI-II Matrix Reasoning	7.85^	18.07	29.52	5.88^	23.30	23.30	13.81	61.11	30.55	74.81	45.50	14.61	22.39

Notes. Shaded areas represent scores which fall below less than 10% of the estimated control population's scores. [a]Assessed at screening [b]Subject sentences not reported as participants were at ceiling ^$p < 0.10$ *$p < 0.05$

3.2.2. Results.

Ten of the 13 poor comprehenders (77%) scored below controls on at least one lexical or conceptual semantics task (PPVT-IV, definition production and recognition, conceptual semantics and ACE 6-11 Naming tasks). Of these, 7 scored below the cut-off on multiple semantic tasks. A small proportion also demonstrated deficits on tasks tapping orthography such as irregular word reading, sight word reading or vocabulary reading (5 participants, 38%) and on the auditory lexical decision task, which tapped knowledge of phonological word form (5 participants, 38%). Thus, the majority of poor comprehenders appeared to have difficulties at the lexical level, primarily in the semantic domain.

Three participants (participants 6, 7 and 8) had scores on par with controls on all lexical and semantic tasks (PPVT-IV, definition production and recognition, conceptual semantics, naming and auditory lexical decision), demonstrating that not all poor comprehenders have vocabulary deficits. However, two of these children scored below controls on the listening comprehension task, and one on the syntax task. In fact, all 13 poor comprehenders scored below controls on at least one task of oral language, whether at the lexical, sentence, or discourse level.

As expected, poor comprehenders had relative strengths in word reading and broader phonological processing skills. Not a single participant scored below controls on nonword reading, only one participant scored below controls on TOWRE Sight Word Efficiency, and a further participant scored below controls on nonword recall. Five poor comprehenders (38%) scored below controls on auditory lexical decision, but given that their phonological processing (nonword recall) skills were intact, these low scores are likely to be a consequence of poor lexical skills.

Only two children scored below our sample of controls on irregular word reading (both were in the normal range using test norms). These children also scored below cut-off on the conceptual semantics assessment. However, there were 8 participants who scored below cut-off on one or more semantics assessment, but whose irregular word reading skills were as good as controls.

Finally, a minority of poor comprehenders had co-occuring deficits in broader cognitive abilities, with two poor comprehenders scoring below controls on Spatial Processing, another on Spatial Recall, and a further two scoring below controls on Matrix Reasoning.

4. Discussion

In order to examine the complex relationship between vocabulary and reading comprehension, we investigated patterns of vocabulary and oral language deficits in a sample of poor comprehenders at both the group and individual level.

4.1. What are the patterns of vocabulary and oral language deficit amongst poor comprehenders?

At the group level, poor comprehenders' scores were significantly lower than controls on the definition production and recognition tasks, replicating previous findings of vocabulary deficits in this population. However, individual level data revealed that not all poor comprehenders had vocabulary difficulties. There were three poor comprehenders (23%) who scored as well as controls on all lexical and semantic tasks, but scored poorly on syntax and listening comprehension tasks. This suggests that vocabulary weaknesses may cause reading comprehension difficulties for some, but not all children. Longitudinal and training studies are required to test this hypothesis.

4.2. Are poor comprehenders' vocabulary deficits primarily semantic in nature?

The majority of poor comprehenders (10 of 13 participants) scored below controls on at least one semantic task. A third of these children also scored below controls on a task of knowledge of phonological word form (the auditory lexical decision task). Poor performance seemed to reflect poor lexical knowledge rather than weak phonological processing skills – all 5 children who scored below controls on this task scored as well as controls on the nonword recall task. Indeed, only one poor comprehender scored below controls on nonword recall. This is consistent with previous literature suggesting that the broader phonological processing skills of poor comprehenders tend to be intact (Catts et al., 2006; Nation et al., 2004).

Thus, poor comprehenders' vocabulary deficits were primarily semantic. However, poor performance on one semantic task did not always entail poor performance on other semantic tasks. This is not surprising given that our semantic tasks relied to different degrees on semantic depth, expressive language abilities and reasoning skills. In our study, no one task was clearly more sensitive than the others, but future research with larger samples should explore the influences of test format and content on children's scores on semantic tasks.

4.3. Are poor comprehenders' weak semantic skills associated with weak irregular word reading abilities?

Our poor comprehenders were selected to have irregular word reading skills within the normal range. According to proponents of the Triangle Model, this should have resulted in a low incidence of semantic difficulties, because intact semantic skills are important for successful irregular word reading (Plaut et al., 1996). As we have shown, this was not the case.

It is problematic that studies of reading comprehension seldom systematically measure irregular word reading abilities (Ouelette & Beers, 2010). The ability to read irregular words is just as crucial for reading comprehension as the ability to read regular words (Ouelette & Beers, 2010; Ricketts et al., 2007). Indeed, it is arguable whether the term "poor comprehenders" should be applied to children who have irregular word reading difficulties, because they do not in fact have age appropriate reading accuracy. Nonetheless, we considered the possibility that some poor comprehenders may have had subtle irregular word reading deficits compared to age-matched controls.

Two poor comprehenders did score below controls on irregular word reading (despite being within normal limits compared to the test's standardisation sample), and both also had semantic deficits. However, 8 of our participants had intact irregular word reading skills despite poor semantic skills. Our study is the first to demonstrate this pattern in poor comprehenders.

Such a finding is consistent with the Dual Route model, which posits that a word's phonology can be accessed directly from its stored orthographic form without access to semantics (Coltheart et al., 1993; Coltheart et al., 2001). However, these findings can also be explained within the framework of the Triangle model (Plaut et al., 1996), even though it proposes that contributions from semantics are particularly crucial for irregular word reading. Under this view, intact irregular word reading in the presence of semantic deficits can be accounted for using the notion of "division of labour" (e.g., Plaut et al., 1996; Harm & Seidenberg, 2004): There are two pathways within the Triangle model, one which relies primarily on links between orthographic and phonological nodes (the phonological pathway), and another which relies on links between orthography, phonology and semantics (the semantic pathway; Plaut et al., 1996). It has been argued that individuals rely on these pathways to differing degrees (Plaut et al., 1996; Woollams, Lambon-Ralph, Plaut & Patternson, 2010). Therefore, if semantic skills were compromised, a child could in theory be able to learn to read irregular words successfully by relying to a greater degree on the phonological pathway.

An alternative possibility has been proposed by Nation and Cocksey (2009), who found that irregular word reading ability was best predicted not by semantic knowledge, but by a child's knowledge of lexical phonology (as measured on a task of auditory lexical decision). Thus, it may be that in order to read an irregular word correctly, a child needs to know how a word sounds, but does not necessarily need to know what it means (Castles et al., 2010; Nation & Cocksey, 2009). However, it is worth noting that a recent study (Ricketts, Davies, Masterson, Stuart & Duff, in press) revealed the opposite finding – in that study, semantic knowledge was more closely associated with word reading than lexical phonology.

We did not find evidence of a clear link between knowledge of a word's lexical phonology and reading ability - four children scored below controls on the auditory lexical decision task, but nonetheless scored as well as controls on irregular word reading and on the vocabulary reading task. However, it is important to note that data was analysed at the subject level[4], and the relationship between knowledge of a word's semantics or lexical phonology and ability to read it aloud is likely to operate at an item level (Nation & Cocksey, 2009; Ricketts et al., in press).

In summary, these findings provide some evidence of a possible dissociation between semantic knowledge and irregular word reading ability, and hence for the Simple View prediction that decoding and oral language abilities can be separately impaired. However, further research exploring item-level relationships between semantics, lexical phonology and reading ability in poor comprehenders is required.

4.4. Heterogeneity in the oral language skills of poor comprehenders

Additional support for a separation between decoding and oral language abilities comes from our finding that there were three poor comprehenders who had no lexical or semantic deficits. These children had intact nonword and irregular word reading accuracy, and intact reading fluency, but had oral language deficits above the word level (i.e., on tasks of syntax and listening comprehension).

[4] We did not explore item-level relationships between semantics, lexical phonology and reading aloud because many of the words in our vocabulary reading task were regularly spelled, so could have been "sounded out" using knowledge of letter-sound relationships

If (as suggested by the Simple View, and supported by our data) different types of reading problems can be caused by different underlying profiles of impairment, then it follows that different types of impairment may require different intervention approaches. Thus, if a child has reading comprehension problems which stem from decoding weaknesses, they should receive decoding intervention, and if a child has reading comprehension problems which stem from oral language difficulties, they should receive oral language intervention (Duff & Clarke, 2011).

Our study has gone beyond this broad distinction to show that oral language difficulties in poor comprehenders can take several different forms. This implies that different children may require different types of oral language intervention. For example, a vocabulary training program may be effective in improving reading comprehension for children with semantic or lexical weaknesses, but it may not be effective for a child with syntactic weaknesses. Critically, studies which analyse outcomes solely at the group level are not capable of detecting these differences, nor of tracking the effectiveness of training outcomes for children with different oral language profiles.

Furthermore, our study has shown that language deficits in poor comprehenders are subtle and may not be detected using standard scores from standardised tests (Catts et al., 2006; Nation et al., 2004). This implies that studies of individual differences in poor comprehenders should compare poor comprehenders to samples of matched controls with average reading comprehension, rather than to standardised test norms.

4. 5. Limitations

It is crucial to note that our study is correlational. We measured poor comprehenders' skills at a single point in time. Some of the deficits we identified may therefore be incidental correlates of comprehension rather than causal factors. Furthermore, our sample size was small, and replication with larger sample sizes is necessary. Finally, our results represent profiles of poor comprehenders in the upper primary grades. The picture may well be different at different stages of development – some deficits may play a role in the early development of reading comprehension, but may no longer be playing a key role by the time the child reaches the upper primary grades (Castles, Kohnen, Nickels, & Brock, 2014; Oakhill & Cain, 2012; Ouelette & Beers, 2010).

Nonetheless, this study has highlighted some crucial theoretical and methodological points in relation to individual differences in vocabulary and other oral language skills across poor comprehenders. Future studies should explore the causal roles of oral language difficulties through both longitudinal and training studies, analysing results at both the group and individual levels.

References

Adams, C., Cooke, R., Crutchley, A., Hesketh, A., & Reeves, D. (2001). *Assessment of Comprehension and Expression 6-11*. Windsor, UK: nferNelson.

Adlof, S. M., & Catts, H. W. (20150. Morphosyntax in poor comprehenders. *Reading and Writing, 28*, 1051-1070. doi: 10.1007/s11145-015-9562-3

Adlof, S. M., Catts, H. W., & Little, T. D. (2006). Should the Simple View of Reading include a fluency component? *Reading and Writing, 19*, 933-958. doi:10.1007/s11145-006-9024-z

Alloway, T. P. (2007). *Automated Working Memory Assessment*. London, UK: Pearson.

Anderson, R. C., & Freebody, P. (1981). Vocabulary knowledge. In J. T. Guthrie (Ed.), *Comprehension and teaching: research reviews* (pp. 77-117). Newark, DE: International Reading Association.

Benjamini. Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society B, 57*, 289-300. doi: 10.2307/2346101

Betjemann, R. S., & Keenan, J. M. (2008). Phonological and semantic priming in children with reading disability. *Child Development, 79*, 1086-1102. doi:10.1111/j.1467-8624.2008.01177.x

Biran, M., & Friedmann, N. (2007). *'Shmita vehar Sinai': picture and word association test.* Tel Aviv, Israel: Tel Aviv University.

Blazely, A. M., Coltheart, M., & Casey, B. J. (2005). Semantic impairment with and without surface dyslexia: Implications for models of reading. *Cognitive Neuropsychology, 22*, 695-717. doi:10.1080/02643290442000257

Cain, K., & Oakhill, J. (2006). Profiles of children with specific reading comprehension difficulties. *British Journal of Educational Psychology, 76*, 683-696. doi:10.1348/000709905X67610

Castles, A., Coltheart, M., Larsen, L., Jones, P., Saunders, S., & McArthur, G. (2009). Assessing the basic components of reading: A revision of the Castles and Coltheart test with new norms. *Australian Journal of Learning Difficulties, 14*, 67-88. doi:10.1080/19404150902783435

Castles, A., Crichton, A., & Prior, M. (2010). Developmental dissociations between lexical reading and comprehension: Evidence from two cases of hyperlexia. *Cortex, 46*, 1238-1247. doi: 10.1016/j.cortex.2010.06.016

Castles, A., Kohnen, S., Nickels, L., & Brock, J. (2014). Developmental disorders: what can be learned from cognitive neuropsychology? *Philosophical Transactions of the Royal Society B, 369*, 20130407. doi:10.1098/rstb.2013.0407

Catts, H. W. (2009). The narrow view of reading promotes a broad view of reading comprehension. *Language, Speech and Hearing Services in Schools, 40*, 178-183. doi:10.1044/0161-1461(2008/08-0035)

Catts, H. W., Adlof, S. M., & Weismer, S. E. (2006). Language deficits in poor comprehenders: A case for the Simple View of Reading. *Journal of Language, Speech and Hearing Research, 49*, 278-293. doi:10.1044/1092-4388(2006/023)

Clarke, P. J., Henderson, L. M., & Truelove, E. (2010). The poor comprehender profile: Understanding and supporting individuals who have difficulties extracting meaning from text. In J. Holmes (Ed.), *Advances in Child Development and Behaviour* (Vol. 39, pp. 79-129). New York, Boston: Academic Press.

Clarke, P. J., Snowling, M. J., Truelove, E., & Hulme, C. (2010). Ameliorating children's reading-comprehension difficulties: a randomized controlled trial. *Psychological Science, 21*, 1106-1116. doi: 10.1177/0956797610375449

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed processing approaches. *Psychological Review, 100*, 589-608. doi:10.1037/0033-295X.100.4.589

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review, 108*, 204-256. doi:10.1037//0033-295X.108.1.204

Crawford, J. R., Garthwaite, P. H., & Porter, S. (2010). Point and interval estimates of effect sizes for the case-controls design in neuropsychology: Rationale, methods, implementations, and proposed reporting standards. *Cognitive Neuropsychology, 27*, 245-260. doi:10.1080/02643294.2010.513967

Crawford, J. R., & Howell, D. C. (1998). Comparing an individual's test score against norms derived from small samples. *The Clinical Neuropsychologist (Neuropsychology, Development and Cognition: Section D), 12*, 482-486. doi:10.1076/clin.12.4.482.7241

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test Fourth Edition*. Minneapolis, MN: Pearson.

Duff, F. J., & Clarke, P. J. (2011). Reading disorders: What are the effective interventions and how should they be implemented and evaluated? *Journal of Child Psychology and Psychiatry, 52,* 3-12. doi: 10.1111/j.1469-7610.2010.02310.x

Elwer, S., Keenan, J. M., Olson, R. K., Byrne, B., & Samuelsson, S. (2013). Longitudinal stability and predictors of poor oral comprehenders and poor decoders. *Journal of Experimental Child Psychology, 115,* 497-516. doi:10.1016/j.jecp.2012.12.001

Friedmann, N., & Levy, H. (2009). Treatment of syntactic movement in syntactic SLI: A case study. *First Language, 29*, 15-50. doi:10.1177/0142723708097815

Friedmann, N., & Lukov, L. (2008). Developmental surface dyslexias. *Cortex, 44*, 1146-1160. doi:10.1016/j.cortex.2007.09.005

Friedmann, N., & Novogrodsky, R. (2002). *BAMBI: Battery for assessment of syntactic abilities in children*. Tel Aviv, Israel: Tel Aviv University.

Friedmann, N., & Novogrodsky, R. (2004). The acquisition of relative clause comprehension in Hebrew: A study of SLI and normal development. *Journal of Child Language, 31*, 661-681. doi:10.1017/S0305000904006269

Friedmann, N., & Novogrodsky, R. (2011). Which questions are most difficult to understand?: The comprehension of Wh questions in three subtypes of SLI. *Lingua, 121*, 367-382. doi:10.1016/j.lingua.2010.10.004

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*, 6-10. doi:10.1177/074193258600700104

Harm, M., & Seidenberg, M. S. (2004). Computing the meanings of words in reading: Cooperative division of labor between visual and phonological processes. P*sychological Review, 111*, 662–720. doi: 10.1037/0033-295X.111.3.662

Hoover, W. A., & Gough, P. B. (1990). The Simple View of Reading. *Reading and Writing, 2*, 127-160. doi:10.1007/BF00401799

Hua, A. N., & Keenan, J. M. (2014). The role of text memory in inferencing and in comprehension deficits. *Scientific Studies of Reading*, *18*, 1-17. doi:10.1080/10888438.2014.926906

Keenan, J. M., & Betjemann, R. S. (2007). Comprehension of single words: The role of semantics in word identification and reading disability. In E. L. Grigorenko & A. J.

Naples (Eds.), *Single-word reading: Behavioural and biological perspectives* (pp. 191-210). New York, NY: Taylor & Francis.

Keenan, J. M., Betjemann, R. S., & Olson, R. K. (2008). Reading comprehension tests vary in the skills they assess: Differential dependence on decoding and oral comprehension. *Scientific Studies of Reading, 12*, 281-300. doi:10.1080/10888430802132279

Keenan, J. M., Hua, A. H., Meenan, C. E., Pennington, B. F., Willcutt, E., & Olson, R. K. (2014). Issues in identifying poor comprehenders. *Annee Psychologique, 114*, 753-777. doi: 10.4074/S0003503314004072

Keenan, J. M., & Meenan, C. E. (2014). Test differences in diagnosing reading comprehension deficits. *Journal of Learning Disabilities, 47*, 125-135. doi:10.1177/0022219412439326

Li, M., & Kirby, J. R. (2014). Unexpected poor comprehenders among adolescent ESL students. *Scientific Studies of Reading, 18*, 75-93. doi: 10.1080/10888438.2013.775130

Nation, K., Clarke, P., Marshall, C. M., & Durand, M. (2004). Hidden language impairments in children: Parallels between poor reading comprehension and specific language impairment? *Journal of Speech, Language and Hearing Research, 47*, 199-211. doi:10.1044/1092-4388(2004/017)

Nation, K., & Cocksey, J. (2009). The relationship between knowing a word and reading it aloud in children's word reading development. *Journal of Experimental Child Psychology, 103*, 296-308. doi:10.1016/j.jecp.2009.03.004

Nation, K., & Snowling, M. J. (1997). Assessing reading difficulties: the validity and utility of current measures of reading skill. *British Journal of Educational Psychology, 67,* 359-370. doi:10.1111/j.2044-8279.1997.tb01250.x

Nation, K., & Snowling, M. J. (1998). Semantic processing and the development of word-recognition skills: Evidence from children with reading comprehension difficulties. *Journal of Memory and Language, 39*, 85-101. doi:10.1006/jmla.1998.2564

Nation, K., & Snowling, M. J. (1999). Developmental differences in sensitivity to semantic relations among good and poor comprehenders: Evidence from semantic priming. *Cognition, 70*, B1-B13. doi:10.1016/S0010-0277(99)00004-9

Neale, M. D. (1999). *The Neale Analysis of Reading Ability Third Edition*. Melbourne, Australia: ACER.

Oakhill, J., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading, 19*, 91-121. doi:10.1080/10888438.2010.529219

Ouelette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. *Journal of Educational Psychology, 98*, 554-566. doi:10.1037/0022-0663.98.3.554

Ouelette, G. P., & Beers, A. (2010). A not-so-simple view of reading: How oral vocabulary and visual-word recognition complicate the story. *Reading and Writing, 23*, 189-208. doi:10.1007/s11145-008-9159-1

Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading, 11*, 357-383. doi:10.1080/10888430701530730

Perfetti, C., & Hart, L. (2002). The lexical quality hypothesis. In L. Verhoeven, C. Elbro, & P. Reitsma (Eds.), *Precursors of funtional literacy* (pp. 189-213). Amsterdam/Philadelphia: John Benjamins.

Pimperton, H., & Nation, K. (2010). Suppressing irrelevant information from working memory: Evidence for domain-specific deficits in poor comprehenders. *Journal of Memory and Language, 62*, 380-391. doi:10.1016/j.jml.2010.02.005

Pitchford, N. J., Funnell, E., Ellis, A. W., Green, S. H., & Chapman, S. (1997). Recovery of spoken language processing in a 6-year-old child following a left hemisphere stroke: A longitudinal study. *Aphasiology, 11*, 83-102. doi:10.1080/02687039708248457

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*, 56-115. doi:10.1037/0033-295X.103.1.56

Ricketts, J., Bishop, D. V., & Nation, K. (2008). Investigating orthographic and semantic aspects of word learning in poor comprehenders. *Journal of Research in Reading, 31*, 117-135. doi:10.1111/j.1467-9817.2007.00365.x

Ricketts, J., Davies, R., Masterson, J., Stuart, M., & Duff, F. (in press). Evidence for semantic involvement in regular and exception word reading in emergent readers of English. *Journal of Experimental Child Psychology.*

Ricketts, J., Nation, K., & Bishop, D. V. M. (2007). Vocabulary is important for some, but not all reading skills. *Scientific Studies of Reading, 11*, 235-257. doi:10.1080/10888430701344306

Snowling, M. J., Stothard, S. E., Clarke, P., Bowyer-Crane, C., Harrington, A., Truelove, E., . . . Hulme, C. (2012). *York Assessment of Reading for Comprehension: Passage Reading. Australian Edition.* London, UK: GL Assessment.

Psychology Software Tools. (2012). E-Prime 2.0. Pittsburgh, PA: Psychology Software Tools.

Tong, X., Deacon, S. H., Kirby, J. R., Cain, K., & Parrila, R. (2011). Morphological awareness: A key to understanding poor reading comprehension in English. *Journal of Educational Psychology, 103*, 523-534. doi:10.1037/a0023495

Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *Test of Word Reading Efficiency*. Austin, TX: Pro-Ed.

Wechsler, D. (2011). *Wechsler Abbreviated Scale of Intelligence Second Edition*. San Antonio, TX: NCS Pearson.

Woollams, A. M., Lambon Ralph, M. A., Plaut, D. C., & Patterson, K. (2010). SD-Squared Revisited: Reply to Coltheart, Tree, and Saunders (2010). *Psychological Review, 117*, 273-283. doi: 10.1037/a0017641

Yuill, N., & Oakhill, J. (1991). *Children's problems in text comprehension: An experimental investigation*. Cambridge, UK: Cambridge.

Appendix A

Words used in Definition, Multiple Choice, Auditory Lexical Decision

and Vocabulary Reading Tasks

abrupt
abundance
ally
amateur
anxious
assist
benefactor
brute
coerce
conceal
confide
conform
conquer
dispute
dubious
enthusiasm
envy
expedition
fatigue
foe
frantic
fury
gradual
harsh
idle
immense
impair
invader
lunge
mingle
mock
modest
naïve
nimble
observe
offend
petty
ploy
precise
prevent
pursue
rebel
regret
request
scarce
scorn
seize
serene
shrewd
shudder
swindle
temptation
tense
triumph
tyrant
unique
urge
vacant
vague
vandal
vicious

Appendix B

Mean Raw Scores on All Measures – Controls

Measure	Grade 4 Controls	Grade 5 Controls	Grade 6 Controls
Age (years:months)	9:7 (2.37)	10:5 (2.00)	11:4 (3.00)
Screening measures			
NARA Comprehension[a]	98.86 (6.08)	98.71 (7.13)	98.83 (6.15)
YARC Comprehension[a]	103.43 (5.21)	99.71 (5.68)	98.67 (3.94)
CC2 Nonword Reading[a]	96.70 (7.37)	98.41 (7.73)	96.7 (7.37)
CC2 Irregular Word Reading[a]	105.44 (4.48)	101.86 (3.87)	102.85 (7.57)
Language, cognitive and fluency measures			
TOWRE Sightword Efficiency[a]	103.29 (6.47)	105.57 (10.65)	106.67 (12.71)
TOWRE Pseudoword Decoding[a]	101.86 (6.10)	106.29 (7.91)	104.67 (5.44)
Vocabulary reading task	46 (6.93)	53.43 (2.77)	51.17 (3.48)
PPVT-IV	170.71 (11.35)	182.00 (8.98)	175.00 (8.39)
Definition production task	53.29 (24.14)	65.71 (19.03)	66.33 (17.91)
Definition recognition task	40.29 (7.53)	45.70 (4.56)	45.50 (3.77)
Conceptual semantics task accuracy	37 (0.76)	36.86 (0.35)	37.17 (0.69)
Conceptual semantics task reaction times	2273.60 (301.14)	2228.90 (386.72)	2008.01 (397.89)
ACE 6-11 Naming	18.14 (1.73)	20.33 (1.89)	19.67 (3.04)
Auditory lexical decision task	95.14 (8.34)	103.43 (5.18)	109 (1.41)
AWMA Nonword Recall	14 (2.83)	16.00 (1.63)	15.83 (2.91)
Syntax task - object sentences[b]	19.14 (1.12)	19.29 (0.88)	19.33 (0.75)
Listening comprehension task	10.57 (4.20)	12.29 (3.61)	10.33 (4.15)
AWMA Spatial Recall Processing	54.17 (16.41)	85.33 (33.23)	83.33 (33.61)
AWMA Spatial Recall	29.33 (20.01)	25.67 (5.41)	24.67 (6.16)
WASI-II Matrix Reasoning	18.71 (4.46)	19.29 (2.25)	18.33 (2.62)

Note. Standard deviations are in parentheses. [a] Assessed at screening. [b] All participants were at ceiling on subject questions, therefore these were not analysed.

Appendix C

Raw Scores on All Measures – Poor Comprehenders

Measure	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13
Grade	4	4	4	4	4	4	4	5	5	5	5	6	6
Age (years:months)	9:1	9:6	9:0	8:11	9:5	9:9	9:8	10:0	9:10	10:2	10:4	11:5	11:3
Screening measures													
NARA Comprehension[a]	80	79	78	83	71	86	84	79	82	71	82	82	96
YARC Comprehension[a]	85	90	98	95	81	77	83	109	96	96	79	97	83
CC2 Nonword Reading[a]	99	103	102	104	98	91	96	111	105	106	92	105	97
CC2 Irregular Word Reading[a]	94	102	105	104	112	110	104	116	122	112	109	103	91
Language, cognitive and fluency measures													
TOWRE Sightword Efficiency[a]	106	101	110	109	91	110	118	127	107	114	116	103	99
TOWRE Pseudoword Decoding[a]	112	101	94	104	93	94	107	139	111	111	103	108	112
Vocabulary reading task /61	37	39	47	40	38	36	48	54	48	51	40	54	52
PPVT-IV	145	151	155	132	149	171	174	183	158	162	155	162	174
Definition production task /183	12	11	16	9	10	20	35	52	42	40	36	33	41
Definition recognition task /61	27	26	24	18	19	33	38	42	40	42	41	31	42
Conceptual semantics task accuracy /38	35	34	37	37	36	38	36	38	37	38	36	36	36
Conceptual semantics task reaction times	2109	2850	2760	3319	2470	1947	2569	2162	2610	2715	2336	2132	2584
ACE 6-11 Naming /25	16	16	13	12	9	18	21	22	20	18	18	18	23
Auditory lexical decision task /122	86	80	82	82	78	91	95	101	97	97	97	107	93
AWMA Nonword Recall	17	16	11	11	17	16	16	14	16	16	8	13	17
Syntax task - object sentences[b]	18	14	19	19	19	18	17	19	15	19	18	16	20
Listening comprehension task /24	4	1	3	4	2	4	14	6	8	1	2	4	8
AWMA Spatial Recall Processing	43	60	47	51	14	32	16	80	49	75	84	54	147
AWMA Spatial Recall	15	17	18	17	7	14	9	25	17	23	24	20	33
WASI-II Matrix Reasoning /30	11	14	16	10	15	15	13	20	18	21	19	15	16

Note. Standard deviations are in parentheses. [a] Assessed at screening. [b] All participants were at ceiling on subject questions, therefore these were not analysed.